SAC 1 – Experimental Comparisons and Fuels (Solutions)

1(a) Calibration factor (CF) of solution calorimeter

Given:

- *I = 5.00 A*
- *V = 6.00 V*
- *t = 240 s*
- *ΔT = 7.5 °C*

Step 1: Electrical energy supplied
E = V × I × t
E = 6.00 × 5.00 × 240 = 7200 J = 7.20 kJ 1-----mark

Step 2: Calibration factor
CF = Energy / ΔT = 7.20 / 7.5 = 0.96 kJ/°C
Answer: CF = 0.96 kJ/°C 1-----mark

1(b) Accuracy / Repeatability

Data: ΔH = −50, −51, −20, −51, −50

Inaccurate, not close to −57

If you account for the outlier in trial 3 the results are repeatable

1(c) Outlier – Trial 3

i. More water used (>250 mL)

ΔT smaller → ΔH smaller (same sign smaller magnitude) 1-----mark

Greater volume of water would give a lower ΔT which leads to a lower ΔH 1-----mark

ii. Less water used (<250 mL)

ΔT larger → ΔH larger (same sign greater magnitude) 1-----mark

Smaller volume would heat the water to a greater temperature 1-----mark

iii. Using 0.2 M solutions (calculation correct):

ΔH should be correct as the stoichiometric ratio will be the same. 1-----mark

More mol of reactant more energy given off and greater the ΔT

Most likely error: Too much water (>250 mL)

1(d) Why solution calorimeter produces results with greater validity.

The solution calorimeter is well insulated preventing energy loss as compared to beaker which loses greater amounts of energy to the environment. 1-----mark
A calibration factor accurately gives the relationship between energy and ΔT 1-----mark

It does not assume all energy released by the reaction is absorbed by the water.

This allows ΔT to accurately reflect energy released, giving a more valid ΔH than the open beaker method. 1-----mark

1(e) Molar heat of combustion of hexane

Given:

- *Mass = 0.860 g, ΔT = 41.9 °C, m = 0.200 kg, c = 4.18 J/g°C, M = 86.2 g/mol*

Step 1: Heat absorbed by water
q = m c ΔT
= 200 × 4.18 × 41.9
= 35.03 kJ 1-----mark

Step 2: Moles of hexane
n = 0.860 / 86.2 = 0.0100 mol 1-----mark

Step 3: Molar heat of combustion
Molar heat of combustion = q / n = 35.03 / 0.00997 = −3.51 X 10^3 kJ/mol
ΔHc = −3.51 X 10^3 kJ/mol 1-----mark

(ii) Thermochemical equation:
$2C_6H_{14}(l) + 19O_2(g) \rightarrow 12CO_2(g) + 14H_2O(l)$ ΔH = −7.02 X 10^3 kJ/mol
1-----mark for balanced equation
1-----mark for correct states
1-----mark for correct ΔH with correct sign.

(iii) *Any plausible random error is accepted. Such an error is not repeated every trial 1-----mark*
eg Evaporation of hexane when cap is left off the spirit burner for a length of time.
This would give a higher mass for the amount of energy absorbed by the water and hence will give a lower molar heat of combustion (ΔH_C) 1-----mark.

(iv) Any plausible systematic error. Heat lost to surroundings → ΔH underestimated (less negative)

1(f) i. Energy profile diagram

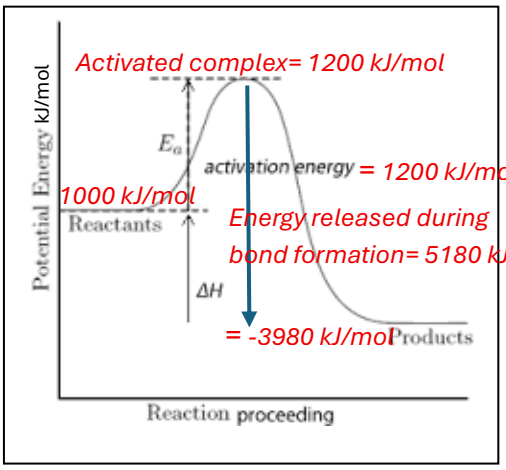
Given: ΔH = −3980 kJ/mol, Ea = 1200 kJ/mol, E(reactants) = 1000 kJ/mol

Activated complex energy
$E_{activated\ complex}$ = E(reactants) + E_a = 1000 + 1200
= 2200 kJ/mol 1-----mark

Products energy
E(products) = E(reactants) + ΔH = 1000 + (-3980)
= −2980 kJ/mol
1-----mark correct value
1-----mark for correct sign

Energy released during bond formation
$Er_{eleased}$ = 2200 − (−2980) = 5180 kJ/mol 1-----mark

1-----mark for correct exothermic profile



ii. Reverse reaction

- *Ea(reverse) = 5180 kJ/mol*
  1-----mark for recognizing that the energy released during bond formation of the forward reaction becomes the activation energy of the reverse reaction.
- *ΔH = +3980 kJ/mol*
  The ΔH for the reverse reaction has the same magnitude but different sign.

2(a) Mass of CO_2 produced when 456 kJ is released (2 marks)

Step 1: Find moles of propane reacted

$1\ mol\ propane \rightarrow 2220\ kJ$
Moles propane $= \frac{456}{2220}$ *1-----mark*
$= 0.20540\ mol$

Step 2: Use mole ratio to find moles of CO_2

From equation

$1\ mol\ C_3H_8 \rightarrow 3\ mol\ CO_2$
$0.20540 \times 3 = 0.615\ mol\ CO_2$ *1-----mark*

Step 3: Convert to mass

Molar mass CO_2 *= 44.0 g* mol^{-1}

Mass $= 0.6162 \times 44.0$
$= 27.1\ g$ *(final answer to 3 sig figs) 1-----mark*

2(b) i. Limiting reactant and excess volume

Reaction: $C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$

Step 1 find the limiting reactant
35.0 litres C_3H_8 *is 35.0 /24.8 =1.41 mol*
190 litres O_2 *is 190 / 24.8 = 7.66 mol*
divide each mol by the coefficient in the equation
=> 1.41/1 =1.41 C_3H_8
=> 7.66/5=1.53 O_2
propane is the limiting reactant.
1-----mark for correct limiting reactant
1-----mark working out.

ii. what is the volume of excess reactant ?
At constant temperature and pressure we can treat volume as mol.
=> 35.0 litres of propane will react with 175 litres (5 X 35.0) of oxygen
1-----mark

=>15.0 litres of oxygen remain. 1-----mark

3(a) USDG and biogas

SDG 7: Affordable and Clean Energy
or
SDG 13 Climate action
1-----mark for an appropriate SDG

Methane is a potent greenhouse gas contributing to climate change if released

Capturing and burning methane produces energy and reduces emissions → supports SDG goal of sustainable energy

1-----mark for a valid explanation.

3(b) Circular economy

Organic waste → biogas → energy → replaces fossil fuels → reduces waste

Demonstrates reuse of resources so circular economy principle satisfied

1-----mark for biogas production and usage is a circular economy
1-----mark for justifying.

4 Consider the two triglycerides shown

a. *The functional groups present are Carbon to carbon double bond (C=C) and the ester functional group.*
   1-----mark for each functional group mentioned. Double bond is not accepted as an answer. Students must specify C to C double bond.
b. *1-----mark - For mentioning the triglyceride A has unsaturated hydrocarbon chains whilst B has saturated carbon chains.*
   1-----mark – saturated methyl esters (biodiesel) pack well in the solid state and so have melting points as the intermolecular forces, dispersion and dipole-dipole, act over smaller distances and exert a greater force of attraction.
   1-----mark – unsaturated methyl esters are kinked and so do not pack well causing weaker intermolecular forces of attraction.
   1----mark - the same trend applies to viscosity as the intermolecular forces of attraction will influence the speed at which molecules are able to flow past each other. Straight chain molecules have a greater surface over which they interact with each other. An explanation that uses surface area to explain viscosity was needed for the mark.